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SUPPLEMENTAL COPY OF APPLICATION

A New Method Of Digital FM Demodulator

BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates to a new method of digital frequency-modulation demodulator and more particularly, to a digital frequency-modulation demodulator that using the structure of time-to-digital converter and the concept of delta-sigma analog-to-digital converter.

2. Description of The Prior Art

Frequency modulation (FM) is one of important and common method in communication system that its receiver end contains the FM demodulation circuit which often using analog design circuit and the traditional analog style FM demodulation circuit including detector circuit and phase-locked loop circuit. If bring the detector into integrated circuit then it need more chip area, and if implement PLL into integrated circuit then an external crystal oscillator is necessary outside this chip.

The modulated signal need the digital signal process after demodulation? then the above two circuit need analog-to-digital converter to convert the demodulated analog signal into digital signal. meanwhile, this analog signal is easy to be interfered by noise signal. However, the digital FM demodulator will first convert the modulation intermediate-frequency (IF) signal

int signal by way of analog-to-digital converter, then using digital signal
pr to demodulate this modulation signal. The analog-to-digital converter
ar signal processor used in digital FM demodulator must have fast
sp demodulate the modulation signal in real time. It also could use
re clock with multiple-fold frequency of modulation signal for sampling
t modulation signal to detect its phase change then demodulate, but
s ology need a high frequency reference clock.
ventional methods of digital RF communication system always need
t the analog signal into digital signal in the receiver end with
c that increasing the circuit complexity. Thus, the demodulation circuit
c the detector circuit or PLL with analog-to-digital circuit could simply
t design also will be one of major objectives today.

SUMMARY OF THE INVENTION

refore a primary objective of the present invention to provide a new
f digital FM demodulator will be applicable in radio communication
esides, the modulation-demodulation section in receiver end also
pplicable in BB call, cellular phone, GPS system, and DECT system.

ext objective of the present invention is to provide a digital FM
tor with two function of modulation-demodulation and analog-to-digital

co The input intermediate-frequency signal pass through this invention
de r will generate a digital signal including high-frequency quantized
si by way of a low-pass filter to filter out above quantized noise signal
to asedband signal.

er objective of the present invention is to provide a digital FM
d r which adopt the PLL structure and utilize the concept of delta-
s og-to-digital converter which without connect external component
a eQUENCY reference clock so that easy for integration.

ention with advantages that not only use delay lines as the timing
but also adopt the concept of delta-sigma analog-to-digital converter
the time-to-digital conversion for digital FM demodulator. This digital
ulator including delay lines, m-to-1 multiplexer, phase
arge pump circuit, quantizer and digital integrator. The modulation
ermediate frequency segment pass through the delay lines with the
around one cycle time and this delayed signal compare its phase
al signal. This compared pulse will go through charge pump circuit
rt into a voltage level stored in capacitor. This quantized voltage is
ed by the digital integrator, then sample another output signal of
s and compare phase with input signal. This system is similar to PLL ,
ck system. The quantized digital signal will feed through low-pass

filter out high frequency noise and get the original modulation signal,
the modulation signal is a digital signal.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings disclose an illustrative embodiment of the present invention
designed to exemplify the various advantages and objects hereof, and are

a.

FIG. 1 is a circuit block diagram of digital FM demodulator according to the
present invention.

FIG. 2 is a circuit waveform of digital FM demodulator according to the present

FIG.

FIG. 3 is a system structure of digital FM demodulator according to the present

FIG.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

refer to Fig.1 that relates to the circuit block diagram of digital FM
 The modulation signal $A_i(t)$ is fed into reference delay lines 11
 delay lines-11 including coarse delay line 111 and fine delay line
 delay time of delay lines 111 and 112 is controlled separately by
 The fine delay lines 112 has multiple output signal
 $A_{i3}(t), \dots, A_{ij}(t)$ which could be expressed as follow:

$$A_{i,j}(t) = A_i(t - T_c - j\tau) \quad (1)$$

T_c fixed delay time of coarse delay lines

τ delay time of fine delay lines

se detector compares the phase difference between A_{id} and A_i , then
 up and down signal. The m-to-1 multiplexer will select one of output
 $A_{i1}(t), A_{i2}(t), \dots, A_{ij}(t)$ from fine delay lines 112 and name it as A_{id}
 rising edge of A_{id} signal lead the A_i signal, up signal will generate
 pulse and its pulse width is just same as the time difference
 rising edges of A_i and A_{id} , but down signal do not generate any
 pulse. The total delay time of A_i signal pass through delay lines is
 and the pulse width will equal to " $T - T_c - d\tau$ " when " $T_c + d\tau$ " smaller
 T of A_i signal.

the way, if the rising edge of A_{id} signal lag the A_i signal, down signal
 generate an effective pulse and its pulse width is also just same as the time
 of A_{id} and A_i signal, and the pulse width will equal to " $T_c + d\tau - T$ ".

is positive when A_{id} lead the A_i signal, on the contrary, its value is negative when A_{id} lag A_i signal. Both effective pulse of up and down signal will charge pump circuit 14 for charging and discharging to capacitor C_c to generate a voltage difference, V_f , and its voltage level is proportional to the phase difference or phase difference of A_{id} and A_i signal. The output of input modulated signal will generate a V_f which is accumulated to capacitor C_c and this stored voltage will be quantized to generate a bit digital signal $y(k)$, $y(k)$ is the output digital sequence of total system. Block 15 is a analog-to-digital converter which could be one bit or multi-bit converter. One bit converter is the comparator. The quantizer 15 in the system adopt one bit voltage comparator. The accumulator 16 accumulate output digital signal $y(k)$, actually, it is simply a digital counter due to quantizer 15 is one bit analog-digital converter. The output signal will select one output A_{id} signal from the fine delay lines through a multiplexer and compare its phase with A_i signal. Consequently, the delay of A_{id} signal is controlled by output signal $y(k)$ it will delay one more unit delay if $y(k)=1$. On the contrary, the delay of A_{id} decrease one unit delay if $y(k)=-1$. This whole system is similar to PLL structure. $Y(K)$ is feedback to control the delay time and make the next rising edge of A_i signal arrive at the same time with rising edge of A_{id} signal simultaneously, so the A_{id} signal is delayed one cycle than A_i signal when the system is locked.

In Fig.2, this is the circuit waveform of digital FM demodulator of the present invention. $T(k)$ is the k th cycle time of input modulation signal. $P(k)$ is the time difference of A_{id} rising edge with next A_i cycle. The value of up signal means $P(k)$ is positive value, but the down signal means $P(k)$ is negative. That is because the maximum frequency shift of input signal is much smaller than carrier frequency. The change of $T(k)$ is related to carrier cycle T_c .

The effective pulse of up signal and down signal only happen at the rising edge of A_{id} and A_i signal and this effective pulse has been transferred to the capacitor C_c by way of charge pump circuit before arriving of the falling edge. This falling edge could be the trigger clock of the quantizer and

so this system do not need external reference clock. As shown in

in diagram, a formula as follows :

$$T(k) = T(k-1) + y(k) * T \quad (2)$$

$$T(k-1) \quad (3)$$

could get;

$$T(k) = T(k-1) + \Delta T(k) + y(k) * T \quad (4)$$

Based on the capacitor voltage at k th cycle based on Fig.2, we could see that the signal is generated by $V(k-1)$ and I_c signal to charge/discharge C_c

own signal effective pulse period and I_b charge/discharge C_c

i.e. the voltage is determined by these three parameters.

C_c for I_c at k th cycle is :

$$\Delta V(k) = \frac{I_c}{C_c} T(k) \quad (5)$$

clock is the input modulation signal A_i , then the C_c voltage level

formula when charge-discharge is at k th cycle.

$$\Delta V(k) = \frac{I_c}{C_c} [T(k) + T(k+1)]/2 \quad (6)$$

$T(k)$

$$\Delta V(k) = \frac{I_c}{C_c} T(k) \quad (7)$$

$$\Delta V(k) = \frac{I_c}{C_c} [T(k) + T(k+1)]/2 + \{I_c/C_c \cdot P(k)\} \quad (8)$$

the maximum frequency shift is much smaller than carrier

$T(k)$ is around equal to carrier cycle T_c

$$\Delta V(k) = \frac{I_c}{C_c} P(k) + y(k) \cdot \frac{I_b}{C_c} T_c \quad (9)$$

A_i

L

next formula :

$$A \cdot P(k+1) + B \cdot y(k)$$

into above formula, then get

$$V(k) = [P(k) + \Delta T(k) + y(k) \cdot T] + B \cdot y(k)$$

The output of $V(k)$ is the total system output.

In Fig.3, is the system structure of digital FM demodulator of the present invention. This diagram is a two level delta-sigma. The input is $\Delta T(k)$ that also is the signal difference of $T(k)$ and $T(k-1)$. The output signal $y(k)$ in present invention is similar to an analog-digital converter output signal. the quantized noise signal is a high frequency segment. So, the output digital signal $y(k)$ is first then filter out quantized noise by the digital filter to get the original signal.

The technology is similar to conventional delta-sigma analog-to-digital. Based on above deduction, the output digital signal is the original signal of original modulation signal. In brief, $y(k)$ signal filter out the noise by way of low-pass digital filter before signal accumulation.

This invention provide a FM digital demodulator which with more advantages than conventional technology as follow:

1. The circuit in present invention will be applicable in radio communication system, besides, the modulation-demodulation section in also could be applicable in BB call, cellular phone, GPS system, system.

2. The invention to provide a digital modulation demodulator which L structure and utilize the concept of delta-sigma analog-to-digital converter which without connect external component and high frequency reference clock so that easy for integration.

3. The invention to provide a digital modulation demodulator with two demodulation and analog-to-digital conversion. The input of high-frequency signal pass through this invention demodulator will be converted to digital signal including high-frequency quantized signal. then by low-pass filter to filter out above quantized noise signal to get the original signal.

It is noted that the above described embodiment of the invention may be carried out without departing from the scope of the invention. Accordingly, to promote the progress in science and the useful arts, the invention is disclosed and is intended to be limited only by the scope of the claims.